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 (71) Applicant: W.R. GRACE & CO.-CONN. [US/US]; 1114 Avenue of the Americas, New York, NY 10036 (US).
 	
 (72) Inventors: BLOCK, Jacob; 14112 Parkvale Road, Rockville, MD 20853 (US). FAN, Xiyun; 2907 Bear Trails, Orange, TX 77632 (US).
 	
 (74) Agent: TROFFKIN, Howard, J.; W.R. Grace & Co.-Conn., 7500 Grace Drive, Columbia, MD 21044 (US).
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(54) Title: IMPROVED ELECTRODE COMPOSITIONS

(57) Abstract

An electrode composition for use as an electrode in a non-aqueous battery system. The electrode composition contains an electrically active powder in a solid polymer and, as a dispersant, a polyester polyamine copolymer that is electrochemically inert. The dispersant is electrochemically inert at 2.5-4.5 volts.

IMPROVED ELECTRODE COMPOSITIONS

Background of the Invention

Field of the Invention:

This invention pertains to battery components,
including electrodes, and cells.

Description of the Related Art:

Storage batteries have a configuration composed of
at least one pair of electrodes of opposite polarity
and, generally, a series of adjacent electrodes of
alternating polarity. The current flow between
electrodes is maintained by an electrolyte composition
capable of carrying ions across electrode pairs.

Non-aqueous batteries have certain distinct
advantages over other types of storage batteries.
They use, as anodes, light weight metals, such as
alkali metals as for example, lithium metal, lithium
oxides, lithium-aluminum alloys and the like which are
at the far end of the electromotive series. These
batteries have the potential for providing much higher
specific energy (gravimetric) and volumetric energy
densities (capacity per unit weight and volume,
respectively) than other types of batteries, due to
the low atomic weight of the metal and high potential

for forming a battery in conjunction with suitable
positive electrodes far removed from the light weight
metal electrode (the description herein will use
batteries having lithium as the light weight metal
5   anode although other light weight metals can be used)
in the electromotive series. The battery can be
formed in any conventional physical design, such
cylindrical, rectangular or disc-shaped "button"
cells, normally of a closed cell configuration.
10   The battery components of positive electrode,
negative electrode and an electrical insulating
material capable of permitting ionic conductivity,
such as porous separator membranes or a solid or gel
polymer electrolyte located between the electrodes.
15   Batteries formed of these components can be in the
form of distinct alternating plates in a sandwich
design or of a continuously spirally wound design as
are well known.
As disclosed in copending U.S. patent
20   applications, U.S. Serial No._____ (Attorney
Docket No. 8788), U.S. Serial No._____
(Attorney Docket No. 8878), U.S. Serial No.
_____ (Attorney Docket No. 9189), and U.S.
Serial No. _____ (Attorney Docket No. 9190),
25   co-assigned with the present application which
teachings are incorporated herein by reference,
methods and battery compositions have been developed
which provide a solid polymer electrolyte-electrode
composite suitable for light weight metal battery
30   systems.
Briefly, the processes involve forming electrodes
composed of active solid material which are co-

extruded with solid polymer electrolyte components to
provide the resultant electrode-electrolyte composite.
Solid material suitable for forming anodes include,
for example, carbons capable of intercalating the
light weight metal ions within its crystal or other
structure, such as graphite or coke and the like.
Solid material suitable for forming cathodes are metal
chalcogenides having a metal selected from Ti, Zr, Nb,
Cu, Fe, Ta, V, Mn, C, Co, Ni and mixtures of these
metals alone or together with intercalating metals,
such as lithium or sodium. Preferred alkali metal
(e.g. lithium) chalcogenides are those of manganese
oxides, cobalt oxides, vanadium oxide or nickel oxides
or mixtures thereof. The most preferred chalcogenides
are lithium manganese dioxide and overlithiated
manganese oxides. The electrochemically active
material is normally used in combination with minor
amounts of up to about 30 wt. % of a conductive carbon
based on the total solids. The conductive carbon may
be a carbon black, such as acetylene black and usually
has a particle size range of from about 1 to 100 mm.

According to the embodiments disclosed, the solid
polymer electrolyte is a blend of an electrolyte salt,
a binder, and an organic liquid capable of solvating
and forming an ionic complex with the salt. The salt
is preferably a lithium salt selected from the group
consisting of $LiPF_6$, $LiAsF_6$, $LiCF_3SO_3$, and $LiClO_4$ and the
like.

The liquids useful in forming the solid polymer
electrolyte include the aprotic organic solvents,
i.e., not prone to contributing a proton, such as
ethylene carbonate, propylene carbonate, dimethyl

carbonate, diethyl carbonate, dimethyl adipate, tetramethylene sulfone, g-butyrolactone, dimethylformamide, dioctyl phthalate, and dibutyl phthalate and the like and mixtures thereof.

5   Polymers typically used in SPE's include polyacrylonitrile (PAN), poly(tetraethylene glycol diacrylate) (PEGDA), poly(vinylidene difluoride) (PVDF) and poly(vinyl pyrrolidinone) (PVP) and the like.

10   The various processes can be used to formulate composite electrolyte-anodes or electrolyte-cathodes, depending on the active electrode material utilized. The compounded composition typically is extruded into a desired shape, such as a sheet, which may be

15   deposited onto a conductive current collector (foil, screen of metal) that can be cut into smaller sizes to form electrodes. The electrodes can then be assembled into batteries.

It is highly desirable to have a formulation that

20   results in a final product having the desired characteristics, and one that is easily handled during processing. In extrusion processes, viscosity of the material is an important concern. The viscosity should be high enough to permit good mixing of the

25   components to provide a homogeneous mass, while not being of such high viscosity to cause excessive back pressure in the extruder. At the same time the final product must have a high content of solid active particulate material to provide a suitable electrode.

30   The formulations and extrusion processes optionally utilize additives to modify various properties of the materials during fabrication, such

as viscosity, and to enhance the characteristics of
the final product. Typical of the additives used are
dispersants. It might be assumed that a wide variety
of dispersants might be useful to obtain the desired

5   results. However, it has been found that, although
there is a large number of dispersants available, most
dispersants do not aid in enhancing the processing
characteristics of the complex mixture of solid
particulate material and solid polymer electrolyte

10   (SPE) components. The SPE materials are generally
fluid, low viscosity compositions under extrusion
processing conditions. In addition, a selection of a
particular dispersant is not obvious to the artisan
when attempting to provide an extruded, highly-filled

15   electrode, due to the many factors that influence the
results one obtains with any particular dispersant.
Among the factors that influence the results obtained
are: (1) the solubility of the dispersant in the
polymer electrode systems and/or organic electrolytes

20   that are required in the application; (2) the chemical
stability of the dispersant at the electrode potential
realizing that many cells are operated at different
potentials; (3) the stability of the electrochemically
active and electrically conductive materials used in

25   combination with a particular dispersant and under the
conditions needed for fabrication; (4) the ability of
the dispersant to allow or enhance binding of the
active materials and other particulate material into a
unitary structure at very low concentrations in order

30   to provide an electrode with good performance; (5) the
ability and ease of obtaining a uniform distribution
of the dispersant with the binder and active material

of the electrode; (6) the ability of the dispersant to
remain stable in an electrode capable of undergoing a
multiplicity of charge-discharge cyclings; (7) the
number and ease of the steps required to obtain the

5   desired electrode; and (8) the safety, availability of
the material, and cost.

Summary of the Invention

10   The present invention is directed to the addition
of polyester/polyamine dispersants that are non-active
and electrochemically stable (inert electrochemically)
which produces a significant viscosity reduction to a
feed mixture which has a high content of solid

15   particulate active electrode material while providing
an electrolyte-electrode composite product. This
enables the obtainment of higher loadings of
electrically active powder in the electrode, e.g.
$LiMn_2O_4$ in the cathode, or carbon in the anode.

20   Preferably, the polyester/amine dispersant is
electrochemically stable at 2.5 to 4.5 volts, most
preferably 2.5-4.2 volts, as determined by standard
procedures.

25   Detailed Description of the Invention:

The present invention is directed to an improved
extrusion process to provide high energy electrode-
electrolyte composite products. The present process

30   has been found to achieve higher loading of solid
active electrode product in which the dispersant is an
electrochemically inert material; and which achieves

good flow-through processing properties within the extruder.

The electrode compositions to which the present invention has been found suitable are those described in co-pending application Serial No._____ (Attorney Docket No. 8788), U.S. Serial No._____ (Attorney Docket No. 8878), U.S. Serial No. _____ (Attorney Docket No. 9189), and U.S. Serial No. _____ (Attorney Docket No. 9190), which teachings are incorporated herein by reference. The present invention can be used most preferably in the process of the above application having Docket Nos. 9190, 8788, and 9189.

It has been unexpectedly found that the addition of certain dispersants which are classified as polyester/polyamine dispersants; - that is having ester and amine hydrophilic groups, provide a significant viscosity reduction during the extrusion processing of the materials; permit very high loading of solid active material; and provide an electrode in which the dispersant is an inert material therein. The polyester/polyamine dispersant must exhibit electrochemical stability (inertness) at an operating range of from 2.5 to 4.5 volts, most preferably from 2.5 to 4.2 volts, as determined by standard battery operating procedures.

Hypermer® KD1, available from ICI Americas, Inc. has been used to particular benefit. Hypermer® KD1 polyester/polyamine, when used as a dispersant in forming polymer electrode compositions, both anode and cathode, produces a significant viscosity reduction without deteriorating the electrochemical performance.

This unexpectedly enables the obtainment of higher
loadings of electrically active powder in the cathode
or in the anode, e.g., $LiMn_2O_4$ in a cathode, or carbon
in an anode.

5   The dispersant can be premixed with one or more of
the components used in forming the desired composite
electrolyte-electrode. Normally the dispersant is
added as part of the initial feed mixture where more
than one feed stream is used. The dispersant is
10   preferably added to the solid active material. The
dispersant should be used in from about 1 to about 3
percent of the total composition.

          The preferred polymeric dispersant, is Hypermer®
KD1. Other Hypermer dispersants having different
15   solubility and stability characteristics have not been
found suitable in achieving the desired result. For
example, a series of these dispersants are known to
have the following characteristics:

          (1) HYPERMER® KD1 for use in medium polarity
20   solvents, e.g., ethers, ketones, THF, chlorinated
hydrocarbons, and blends of these solvents.

          (2) HYPERMER® KD2 for use in highly polar
solvents, e.g., ethanol, iso-propanol, 2-ethyoxy
ethanol and some aqueous systems.

25   (3) HYPERMER® KD3 and HYPERMER® KD4 for use in
non-polar systems, e.g., mineral spirits, toluene,
xylene, paraffin waxes and oils. Additional
characteristics of certain hypermer products are shown
in the following Table A:

30

TABLE A

Physical Characteristics

HYPERMER® Polymeric Dispersant	Appearance	Melting Point °C	Specific Gravity	Viscosity (cps)	Effective Solvent Polarity Range
KD1	Tan colored flakes	Softens 60°C	1.05	N/A	Medium Polar
KD2	Straw colored liquid	N/A	1.02	200-320 at 20°C	Highly Polar
KD3	Amber liquid/ paste	Pourable 25°C	0.92	1600-2200 at 35°C	Non-polar

5

The nature of the invention will be made clearer by the following examples:

Example 1

10

This example shows how the viscosity of a solid polymer electrolyte (SPE) mixture (without the electrically active component) is determined.

A solid polymer electrolyte composition according

15 to the present invention was prepared, as follows:

Solid Polymer Electrolyte (SPE)

wt. % Component

20 44   Ethylene Carbonate (Aldrich)

44   Propylene Carbonate (Grant Chemicals)

6   Polyacrylonitrile (Eastern Chemical)

6   Lithium (bis) trifluoromethanesulfonimide (3M)

25   The mix was heated to 120°C while mixing to form a uniform mixture.

The viscosity of the mixture was determined as follows:

A Brookfield RVT-DV-II viscometer was used with a "Thermosel" attachment. The temperature was 125°C. A number 27 spindle was used. The viscosity of this mixture was found to be 150 cp at shear rates between 6.8-34 sec^{-1}.

Example 2

This example compares the viscosity of the basic SPE mixture of Example 1 with the same mixture containing an electrically active component ($LiMn_2O_4$), such as would be used to form an electrolyte-electrode composite according to the present invention.

$LiMn_2O_4$ powder (obtained from the Davison Chemical Division of W.R. Grace) (20.17 parts per 10 parts SPE) was added to the mixture of Example 1, and the viscosity was determined as in Example 1. The viscosity was found to have increased to 12,500 cp at 6.8 sec^{-1}. At 3.4 sec^{-1}, the viscosity was 16,400 cp, and at 0.85 sec^{-1}, the viscosity was 76,800 cp.

Example 3

This example shows the effect of various organic-soluble dispersants on the viscosity of the electrolyte-electrode mixture of Example 2.

Various commercially available dispersants were added to the mixture of Example 2, and the viscosity determined as in Example 1. The results are summarized in Table I.

Table I

Dispersant	Dosage (g/10 g SPE = 20.17 g LiMn2O4)	Viscosity (cp)	Shear Rate (sec⁻¹)
Hypermer® KD1 (ICI)	0.2	6,200	3.4
Hypermer® KD3 (ICI)	0.2	20,200	3.4
OLOA 1200 Chevron	0.2	21,800	3.4
Hypermer® KD2 (ICI)	0.2	57,200	0.85

These results show that only the Hypermer® KD1 produced a significant viscosity reduction, whereas the other dispersants actually increased viscosity.

Example 4

This example shows the effect of the addition of acetylene black to the SPE mixture, such as would be added to form an electrolyte-electrode composite according to the present invention.

Acetylene black (Chevron)(1.36 parts) was added to 20 parts of SPE from Example 1. The rheology of this mix was determined at 125°C using a number 29 spindle. The results are summarized in Table II below.

Table II

Shear Rate (sec⁻¹)	Viscosity (cp)
1.7	180,000
0.85	276,000
0.34	468,000
0.17	772,000

Example 5

This example shows the effect of Hypermer® KD1 on the viscosity of the mixture of Example 4.

Hypermer® KD1 (0.2 parts) was added to the mixture of Example 4, and viscosity measured at 125°C with a number 29 spindle. The results are summarized in Table III below.

Table III

Shear Rate (sec^{-1})	Viscosity (cp)	% Reduction
1.7	32,600	82
0.85	51,000	82
0.34	115,000	75
0.17	240,000	69

The results show a 69-82% viscosity reduction with Hypermer® KD1.

Example 6

This example shows the effect of $LiMn_2O_4$ addition on the viscosity of SPE and acetylene black.

To the mixture described in Example 4 (33.6 parts SPE, 1.9 parts acetylene black) was added 25.5 parts $LiMn_2O_4$. The viscosity was determined at 125°C with a number 29 spindle and is summarized in Table IV below.

<u>Table IV</u>

<u>Shear Rate (sec^{-1})</u>	<u>Viscosity (cp)</u>
1.7	142,000
0.85	233,000
0.34	370,000
0.17	750,000

<u>Example 7</u>

5

    This example shows the effect of Hypermer® KD1 on the mixture of Example 6.

    To the mixture of Example 6 was added 0.67 parts of Hypermer® KD1. The viscosity was determined as in

10   Example 6. The results are summarized in Table V below.

<u>Table V</u>

<u>Shear Rate (sec^{-1})</u>	<u>Viscosity (cp)</u>	<u>% Reduction</u>
1.7	24,400	83
0.85	24,400	89
0.34	64,000	83
0.17	134,000	83

15   These results show that Hypermer® KD1 reduces the viscosity of a cathode mixture 82-90%.

Example 8

This example shows the effect of Hypermer® KD1 on the viscosity reduction of the anode formulations.

5   Table VI lists the formulations of each anode sample which were tested, the sample mixing conditions using the Haake Torque Rheometer, the sample viscosity measured at four different shear rates using the Instron capillary rheometer, and the sample viscosity

10   drop due to the addition of the Hypermer® KD1 at 2200 1/sec shear rate.

a)   As shown in Table VI, Row 1 and 2, adding 1.5w% of Hypermer® KD1 to an anode mixture having 45 v% solid loading results in a 46%

15   viscosity reduction.

b)   As shown in Table VI, Row 1 and 3, adding 2.0 w% of Hypermer® KD1 to an anode mixture having 45 v% solid loading results in a 62% viscosity reduction.

20   c)   As shown in Table VI, Row 4 and 5, adding 1.66 w% of Hypermer® KD1 to an anode mixture having 50 v% solid loading results in a 9% viscosity reduction.

d)   As shown in Table VI, Row 4 and 6, adding

25   2.6 w% of Hypermer® KD1 to an anode mixture having 50 v% solid loading results in a 48% viscosity reduction.

30

TABLE VI

The effect of Hypermer® KD1 on the anode viscosity drop.

ANODE HAAKE/INSTRON DATA

Line No.	FORMULATION				MIXING CONDITION			Instron visc. (poise) at 125°C at shear rate (1/sec)				% visc drop at 2200 (1/sec)
	solid		wt%SPE	Wt% Hypermer KD1	temp (°C)	rpm	time (min)	220	730	2200	7300	
	vol%	wt%										
(1)	45.0	58.0	42.0	0	115	110	12	2100	1060	534	245	0
(2)	45.0	58.0	41.5	1.5	115	110	10	1365	508	290	112	46
(3)	45.0	58.0	40.0	2.0	115	110	10	1245	490	204	103	62
(4)	50	63.0	37.0	0	115	110	15	3260	1500	760	400	0
(5)	50	63.0	35.34	1.66	115	110	12	3840	1560	690	365	9
(6)	50	63.0	34.4	2.60	115	110	20	1600	686	396	250	48

Example 9

This example shows the effect of Hypermer® KD1 on the viscosity reduction of the cathode formulations. Table III lists the formulations of each cathode sample being tested, the sample mixing conditions using the Haake Torque Rheometer, the sample viscosity measured at four different shear rates using the Instron capillary rheometer, and the sample viscosity drop due to the addition of the Hypermer® KD1 at 2200 1/sec shear rate.

a) As shown in Table VII, Rows 1 and 2, adding 2.0 w% of Hypermer® KD1 to a cathode mixture having 45 v% solid loading results in a 12% viscosity reduction.

b) As shown in Table VII, Rows 3 and 4, adding 3.0 w% of Hypermer® KD1 to a cathode mixture having 48 v% solid loading results in a 50% viscosity reduction.

c) As shown in Table VII, Rows 5 and 6, adding 3.0 w% of Hypermer® KD1 to a cathode mixture having 50 v% solid loading results in a 59% viscosity reduction.

d) As shown in Table VII, Rows 5 and 7, adding 4.0 w% of Hypermer® KD1 to a cathode mixture having 50 v% solid loading results in a 61% viscosity reduction.

TABLE VII

The effect of Hypermer® KD1 on the cathode viscosity drop.

ANODE HAAKE/INSTRON DATA

Line No.	FORMULATION solid vol%	FORMULATION solid wt%	wt%SPE	wt% Hypermer KD1	MIXING CONDITION temp (°C)	rpm	time (min)	Instron visc. (poise) at 125°C at shear rate (1/sec) 220	730	2200	7300	% visc drop at 220C (1/sec)
(1)	45.0	71.0	29.0	0	120	110	12	3320	1320	620	300	0
(2)	45.0	71.0	27.0	2.0	120	110	12	2200	1216	545	246	12
(3)	48.0	73.0	27.0	0	120	110	12	5000	2170	1150	470	0
(4)	48.0	73.0	24.0	3.0	120	110	10	2560	1150	570	300	50
(5)	50	75.0	25.0	0	120	50	30	6000	2850	1600	650	0
(6)	50	75.0	22.0	3.0	120	110	20	3270	1150	656	310	59
(7)	50	75.0	21.0	4.0	120	110	20	2580	1200	622	320	61

Example 10

This example shows the effect of Hypermer® KD1 on
the anode film processability and film quality. Table
5   VIII lists the formulations used in the
extrusion/calendering process and the processing
results in terms of film thickness (Film H), film
width (Film W), and die flow uniformity and film
dimensional stability. Table IX gives the
10   corresponding extrusion/calendering conditions used
for each of the runs.

      a)   As shown in Table VIII, row 1 and 2 adding
0.5% Hypermer® KD1 to an anode mixture
having 45 v% solid loading reduced the blank
15   thickness from 15-20 mil to 10 mil, and
improved the die flow uniformity, and the
film width dimensional stability.

      b)   As shown in Table VIII, row 3 and 4, adding
1.66% Hypermer® KD1 to an anode mixture
20   having 50 v% solid loading greatly improve
the processability. Without Hypermer® KD1
this material was not extrudable due to a
very high viscosity caused by the high solid
loading. Adding 1.66% Hypermer® KD1
25   achieved a film having 4-5 mil thick and 7-8
inches wide.

TABLE VIII – Effect of Hypermer® KD1 on the Anode Film Processing.

Line No.	FORMULATION		RESULTS					
	Solid Loading	Hypermer® W%	Blank H Mil	Film H Mil	Blank W Inch	Film W Inch	Die Flow	Film Dimension Stability
(1)	45 v% (58 W%)	0	15-20	3-5	7-8	Varied	Full die flow, but uneven edge tearing due to a slow flow rate.	Film width varied.
(2)	45 V% (58 W%)	0.5	10	4-5	4	4	Full die flow, fairly even and stable.	Film width was fairly stable at 4 inches.
(3)	50 V% (63 W%)	0	-	-	-	-	Extruder jammed.	-
(4)	50 V% (63 W%)	1.66	25-30	4-5	7-8	varied	Full die flow, uneven, edge slow.	Film width varied.

TABLE IX – Anode Extrusion and Calendering Conditions[1]

Line No.	FORMULATION	EXTRUDER					DIE		CALENDER		
		Temp(1-5) (°C)	Screw (RPM)	Feed (#/hr)	TQ (%)	Pressure (psi)	Temp (°C)	Gap (mil)	Roll T(°F) top/bot	Nip gap (mil)	Roll V (ft/min)
(1)	45.0 v% (58w%) 0% Hypermer® KD1	115-115-115-110-75	130	17-25	14	760	121	3	45/240	1-1.5	9-15
(2)	45.0 v% (58w%) 0.5% Hypermer® KD1	123-123-120-95-75	130	17-25	10	650-530	125	1.5-2	45/240	1-1.5	20
(3)	50 v% (63w%) 0% Hypermer® KD1	120-120-120-95-75	130	17-25	12	>2400 Extruder jammed	125	3	45/240	1-1.5	8-15
(4)	50 v% (63w%) 1.66% Hypermer® KD1	121-121-121-95-75	130	17-25	11	810	126	3	45/240	1-1.5	8-15

1 – The corresponding processing results are given in Table VIII, under the same line number.

Example 11

This example shows the effect of Hypermer® KD1 on
the cathode film processability and film quality.
5   Table X lists the formulations used in the extrusion/
calendering process and the film processing results in
terms of film thickness (Film H), film width (Film W),
as well as die flow uniformity and film dimensional
stability. Table XI gives the corresponding
10   extrusion/calendering conditions used in each of the
runs.

      a)   As shown in Table XI, row 1 and 2, adding 2%
Hypermer® KD1 to a cathode mixture having 45
v% solid loading improved the die flow
15   uniformity thus improved the film width
stability.

      b)   As shown in Table XI, row 3 and 4, adding
3.0% Hypermer® KD1 to a cathode mixture
having 48 v% solid loading greatly improve
20   the processability. Without Hypermer® KD1
the die flow was very uneven, and large
portion of the die was blocked due to high
viscosity of the material. Adding 3%
Hypermer® KD1 greatly reduced the die
25   blocking, improved the die flow uniformity,
and stabilized the process. We were able to
get a film with 7 inch wide and the process
was fairly stable and lasted for 20 minutes.

TABLE X

Effect of Hypermer® KD1 on Cathode Film Processing

Line No.	FORMULATION						RESULTS	
	Solid Loading	Hypermer® W%	Blank H Mil	Film H Mil	Blank W Inch	Film W Inch	Die Flow	Film Dimension Stability
(1)	45.4 V% (71 W%)	0	12-15	4-7	4.5	varied	Die blocked seriously. Uneven flow, strips.	Film width varied considerably.
(2)	45.4 V% (71 W%)	2	10-12	8-9	6	6.5	Die flow was fairly even and stable. Die edge blocked.	Film width was fairly stable at 6.5 inches.
(3)	48 V% (73 W%)	0	15-16	4-7	4-2	varied	Die blocked seriously. Severe, uneven flow.	Film width varied considerably.
(4)	48 V% (73 W%)	3	13-15	9-10	7	7.5	Die flow was fairly even and stable.	Film width was fairly stable at 7.5 inches. The process continued for 20 minutes.

TABLE XI

Cathode Extrusion and Calendering Condition[1]

Line No.	FORMULATION	EXTRUDER				DIE			CALENDER		
		Temp(1-5) (°C)	Screw (RPM)	Feed (#/hr)	TQ (%)	Pressure (psi)	Temp (°C)	Gap (mil)	Roll T(°F) top/bot	Nip gap (mil)	Roll V (ft/min)
(1)	45.4 v% (71w%) 0% Hypermer KD1	118-118-110-95-75	110	45-60	49-56	450-550	128	3	45/240	1-2	13
(2)	45.4 v% (71w%) 2% Hypermer KD1	120-120-120-95-75	130	37	10	380-400	115	2-3	45/240	1-2	8-10
(3)	48 v% (73w%) 0% Hypermer KD1	134-127-124-117-104	160	60-50	46	2100-900	130-135	3	45/240	1-2	
(4)	48 v% (73w%) 3% Hypermer KD1	118-118-110-95-75	150	38-60	15	670-690	120	3	45/240	1-2	11-13

[1] The corresponding processing results are given in Table X under the same line number.

Example 12

This example shows that Hypermer® KD1 does not adversely affect cell performance. Cells were prepared with and without Hypermer® KD1. The data in the following Table XII are the average performances of three control cells and three Hypermer® KD1 cells, respectively. Both cells were made with 5 mm coke (Conoco). At cycle 30, the Hypermer® KD1 cells have an average capacity of 6.3 mAh, with a current efficiency of 100% (within the error of the measurement). There has been no measurable degradation since cycle 5.

Table XII

Cell	Theoretical Capacity (LiC)	Capacity (LiMn O.) (100mAh/g)	Capacity Cycle 1	Efficiency Cycle 1	Capacity Cycle 5	Efficiency Cycle 5
Control	22 mAh	11.3 Mah	6.2 mAh	54.6%	7.8 mAh	96.8%
Control + 2% Hypermer® KD1	13.7	12.1	4.7	54.3	6.3	98.7

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. The present invention is to be limited not by the specific disclosure herein, but only by the appended claims.

What is Claimed is:

1.   An electrode composition containing an
electrically active powder in a solid polymer and, as
a dispersant, a polyester polyamine copolymer that is
electrochemically inert.

2.   A composition according to claim 1 wherein
said electrode is a cathode and said electrically
active powder is lithium manganese dioxide ($LiMn_2O_4$) or
overlithiated manganese oxide.

3.   A composition according to claim 2 wherein
said composition comprises ethylene carbonate,
propylene carbonate, polyacrylonitrile, lithium
(bis)trifluoromethanesulfonimide, $LiMn_2O_4$, acetylene
black, and said dispersant.

4.   A composition according to claim 1 wherein
said electrode is an anode and said electrically
active powder is carbon capable of having lithium ion
intercalated within its structure.

5.   The composition according to claim 1 wherein
said dispersant is electrochemically inert at 2.5-4.5
volts.

6.   The composition according to claim 1 wherein
said dispersant is electrochemically inert at 2.5-4.2
volts.

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01M 4/62
US CL :429/ 214, 215, 217, 218, 250

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 429/ 214, 215, 217, 218, 250

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,358,801 A (BRODD) 25 October 1994, col. 14, lines 9-21; col. 6, lines 26-60; col. 15, lines 31-35.	1
A	US 3,918,989 A (GILLMAN et al.) 11 November 1975	1-6
A	KIM, YOUNG-WOOK et al., Tape Casting of Silicon Nitride, Materials Research Society Fall Meeting, Boston, MA, November 1992. (Abstract)	1-6

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 JULY 1997	2 6 SEP 1997

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer CAROL CHANEY
Facsimile No. (703) 305-3230	Telephone No. (703) 308-0661

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INTERNATIONAL SEARCH REPORT

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

CA, WPIDS, INSPEC, COMPENDEX, USPATFULL
search terms: Hypermer?; polyester# or polyamine#; electrode# or cathode# or anode#; electrochem? (3a) (inert or nonconduct? or conduct?)

Form PCT/ISA/210 (extra sheet)(July 1992)*